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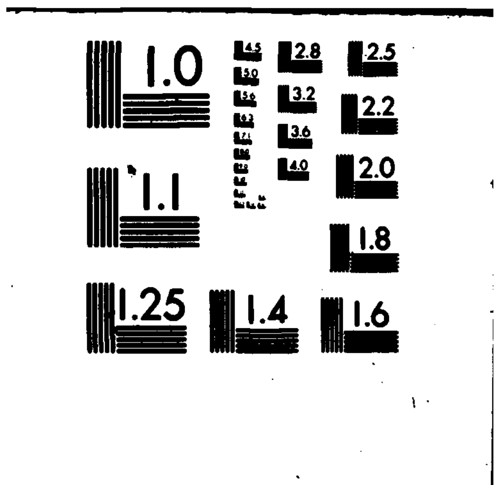

MICROCOPY RESOLUTION TEST CHART

CONTROL OF PARASITIC CURRENTS ON RADIATING SYSTEMS

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I. INTRODUCTION:

Military communication antennas operating in the 2-30 MHz high frequency (HF) band, 30-90 MHz very high frequency (VHF) band, and the 200-400 MHz ultra high frequency (UHF) band are installed on vehicular, shipborne, airborne, manpack, or fixed platforms. Short, medium and long range radio is supported by HF, Net Radio is serviced by VHF, and ground-to-air communication employs UHF. The antenna engineer is confronted with the task of designing small efficient radiating systems having wide bandwidth and predictable impedance and radiation characteristics. In the past, wide bandwidth has been achieved at HF and VHF by band switching and broadband matching circuits. However, new requirements for wide instantaneous bandwidth (no tuning) antennas have been imposed with the advent of frequency hopping radios.

Antenna interaction (mutual coupling) and electromagnetic compatibility (EMC) are major concerns when many antennas and communication systems are collocated in a confined area, as in a command post or an air traffic control facility. System performance may be unpredictable due to antenna mutual coupling effects. The purpose of this paper is to demonstrate, by computer analysis, and *validating experimental measurements*, that extraneous parasitic radio frequency (rf) currents on radiating systems can impair performance, causing field pattern distortion, crosstalk interference, and unpredictable behavior with changes in operating frequency. It is shown that parasitic currents can be suppressed in both narrowband and wideband radiating systems. The techniques discussed are practical and are applicable to field use where accepted procedures for antenna installation are sometimes set aside because of lack of understanding, or for expediency.

This paper is organized as follows: the horizontal dipole above ground is studied, and it is shown that parasitic currents on the sheath of the coaxial feed line can be suppressed. Similarly, the inverted-V

dipole is shown to have significant parasitic feed line currents which can also be eliminated. Extraneous rf currents on the mast supporting a vertical dipole are shown to be substantially reduced over a narrow frequency range by the addition of a quarter-wave detuning stub and over a much wider frequency range by means of a broadband cable choke. Associated radiation patterns confirm the improvement obtained when parasitic currents are suppressed. A broadband colinear dual antenna providing more than 35 decibels (dB) of inter-dipole isolation is described. The high isolation results from the colinear antenna arrangement, and by virtue of the special feed line "Isolator Section" which acts as a band elimination filter for the parasitic currents induced on the feed line of the upper dipole. This antenna system allows duplex operation free from crosstalk interference in an air traffic control facility.

II. PARASITIC CURRENTS ON HORIZONTAL DIPOLES

The horizontal dipole center fed by coaxial line is extensively used. It is known that unequal electromagnetic forces on each half of this antenna cause a condition of imbalance which may result in unequal currents in the antenna arms. The feed line coupled to the antenna may support parasitic currents of appreciable magnitude. In an earlier experimental study, the currents on a horizontal dipole above ground were measured (1). This earlier study demonstrated conclusively, that significant current imbalance may occur. It also showed that current balance in the antenna arms could be improved by simply connecting a cable choke between the dipole and the feed line. In essence, the cable choke acts as an effective high impedance circuit which interrupts the rf current flowing on the outer surface of the feed line.

For comparison purposes, the experimental horizontal dipole was modeled on the Numerical Electromagnetic Code (NEC), a computer program for analyzing the electromagnetic response of antennas (2). The antenna is shown in Fig. 1. To facilitate measurements of current distribution, the experimental dipole was installed seven feet above the ground, and it was modeled on the computer accordingly. In the computer model perfectly conducting ground was assumed and the bottom of the feed line was assumed to be connected to the ground.

Although the length of the modeled antenna is a half wavelength at 4 MHz, such an antenna might be operated in the field at other frequencies without bothering to adjust its length to resonance. To investigate this possibility, the current amplitude distribution at 2 MHz was determined, and is shown in Fig. 1 by the dashed line curve. The experimental and computed distributions are similar. It is seen that the current imbalance is pronounced and that the feed line supports a parasitic current of appreciable amplitude on its outer surface.

As stated earlier, a cable choke was used to suppress parasitic current on the feed line and to improve current balance on the arms of the experimental dipole antenna. A cable choke consists of coaxial cable shaped into a helical coil, as shown in Fig. 2(a), or in the form of a toroid. In the experimental study, the cable choke consisted of thin coaxial cable wound on several high permeability ferrite toroids. Regardless of the construction, however, the cable choke impedance between points A and B at the outer surface of the transmission line (see Fig. 2(a)) is essentially equivalent to a high impedance circuit consisting of an inductance L connected in parallel with capacitance C, as shown in Fig. 2(b). When losses are neglected, the reactance of the choke is, to good approximation, given by $X = 2\pi fL/ \ (1 - (f/fo)^2)$ where the self resonance frequency is $fo = 1/2\pi\sqrt{LC}$. In practice, cable choke losses will be present and should be minimized.

In wide bandwidth applications, it is practical to design the cable choke so that it resonates at the geometric mean frequency $f_o = \sqrt{f_L \, f_U}$ where f_L and fu denote, respectively, the lower and upper frequency limits. When so designed, the reactances at the frequency limits will be equal in magnitude. The bandwidth of the cable choke is inversely proportional to the self capacitance. Thus, to maximize the isolation bandwidth, the cable choke should be designed for maximum inductance and minimum capacitance.

When the cable choke was connected between the dipole and the feed line, in the manner shown in Fig. 3, it was found that the parasitic current on the feed line was essentially eliminated, and the antenna current balance was improved. The impedance of the cable choke used with the experimental diple antenna was (3120 + j4550) ohms at 2 MHz (1). The effect of this choke was accounted for in the NEC computer model by inserting this impedance between one arm of the dipole and the feed line. It is seen that the calculated and measured currents are comparable. Although not shown here, similar improvements in the current distribution are effected at 4, 6, and 8 MHz, demonstrating that the cable choke provides an effective means of suppressing parasitic currents over a broad frequency range.

III. PARASITIC CURRENTS ON INVERTED-V DIPOLES

The inverted-V dipole with drooping arms is an easily erected antenna requiring only one support at its midpoint. As in the previous example, the NEC computer program was used to obtain the current distributions with the feed line connected directly to the antenna and with a cable choke interposed. The inverted-V shown in Fig. 4 is resonant at approximately 7 MHz. At resonance, currents in the antenna arms are well balanced and the feed line excitation is minimal. However, if the antenna is operated

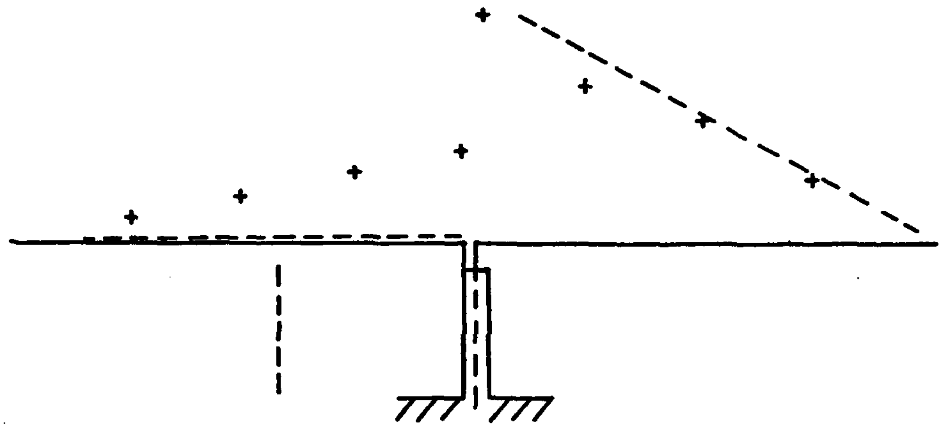

Fig. 1. Horizontal dipole with unbalanced currents;
--- computed + measured

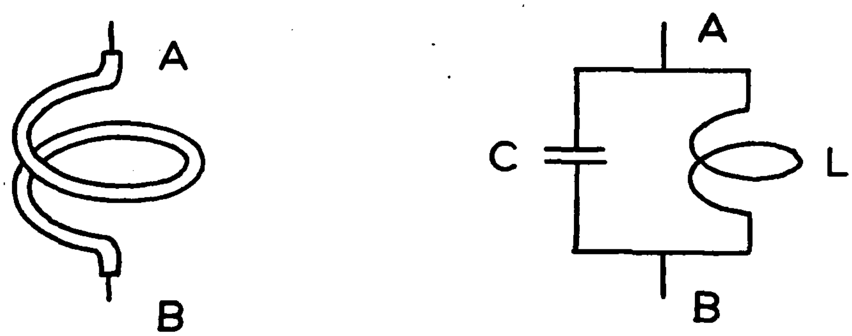

Fig. 2. (a) Cablechoke (b) Equivalent circuit

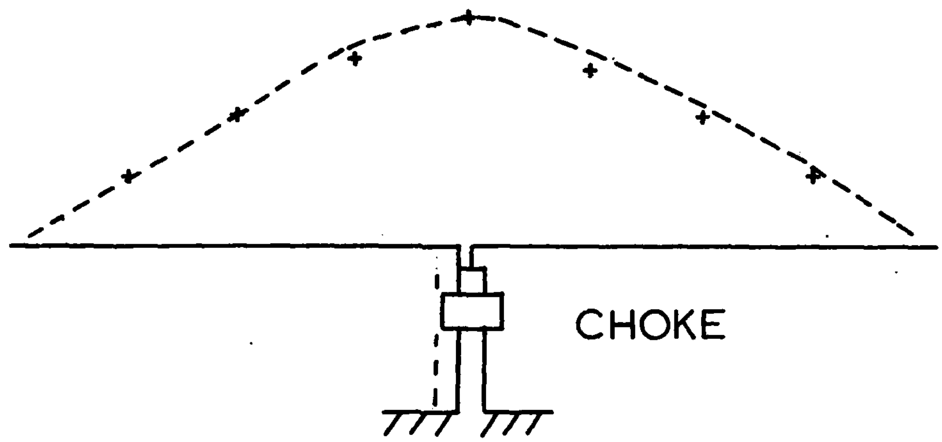

Fig. 3. Horizontal dipole with balanced currents;
--- computed + measured

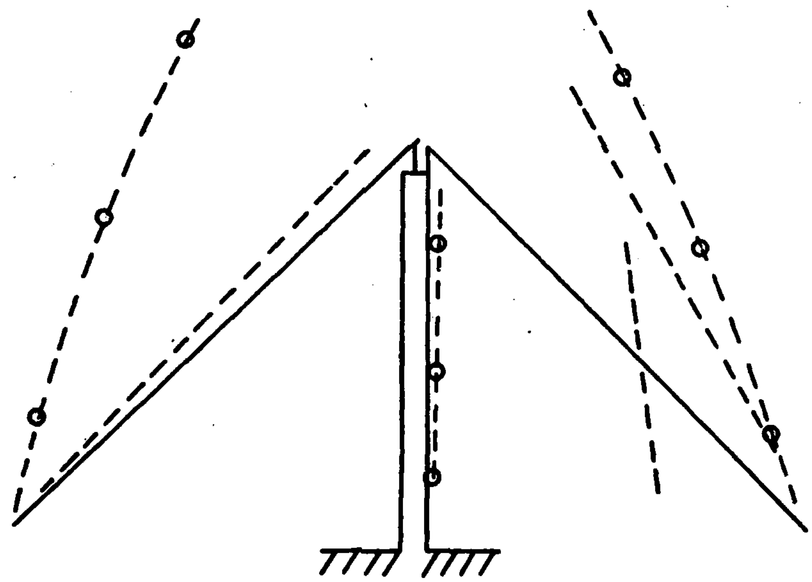

Fig. 4. Currents on inverted-V dipole
--- without cable choke and -o- with cable choke

at frequencies above or below resonance, current imbalance and feed line excitation will increase. The current amplitude distribution obtained at 4 MHz, for example, confirms this expectation. See Fig. 4. Note that in this computer model, the lower end of the feed line is assumed to be connected to perfectly conducting ground.

The inverted-V dipole with a cable choke connected in series with the feed line was also investigated. The impedance of the cable choke at 4 MHz is assumed to be (3935 + j2937) ohms. The lower end of the feed line in the model does not contact the ground, simulating an ungrounded installation. In the computer model "average" ground having a relative permittivity of 15 and conductivity of .005 mhos per meter was assumed. It is seen in Fig. 4 that the cable choke eliminates parasitic current on the sheath of the feed line and balances current in the antenna arms. It is interesting to note that the inverted-V feed-point impedance is (30.1 - j857) ohms with the cable choke present and is (542 + j1942) ohms without the cable choke. This change in impedance is attributed to the markedly different current distributions obtained for the two cases. If a metal support mast is used, an insulator should be provided at its top to prevent "short-circuiting" the cable choke.

IV. PARASITIC CURRENTS ON MAST-MOUNTED DIPOLES

Mast-mounted vertical dipoles are extensively used at VHF and at UHF. The dipole can be electrically decoupled from its support by attaching a quarter-wavelength detuning stub to the mast, or to the feed line as shown in Fig. 5(a). Provided that the stub is properly dimensioned, it introduces a high impedance at the lower end of the dipole cutting off the line current or mast current below. The current amplitude on the resonant stub is maximum at the shorted end. The section of feed line or mast adjacent to the stub carries both the antenna current and the transmission line current. The transmission line currents are in opposite directions in the stub and adjacent mast so that the resultant current is small. Other applications of stubs appear in the literature (3, 4).

If the length of the stub is somewhat different from a quarter-wavelength at the operating frequency, it is then ineffective because its impedance is too low to enforce a current minimum on the mast. This is illustrated in Fig. 5(b), where the non-resonant stub has little effect. Evidently, detuning stubs are effective but in narrowband applications.

When the mast currents are suppressed, as in Fig. 5(a), it is found that the field strength on the horizon increases. Conversely, the field strength on the horizon is reduced when parasitic current is not suppressed. The vertical radiation patterns for these two cases are shown in Fig. 6. For the assumed conditions, the power gain on the horizon is increased by more than 6 dB by suppressing the mast currents. This, of course, trans-

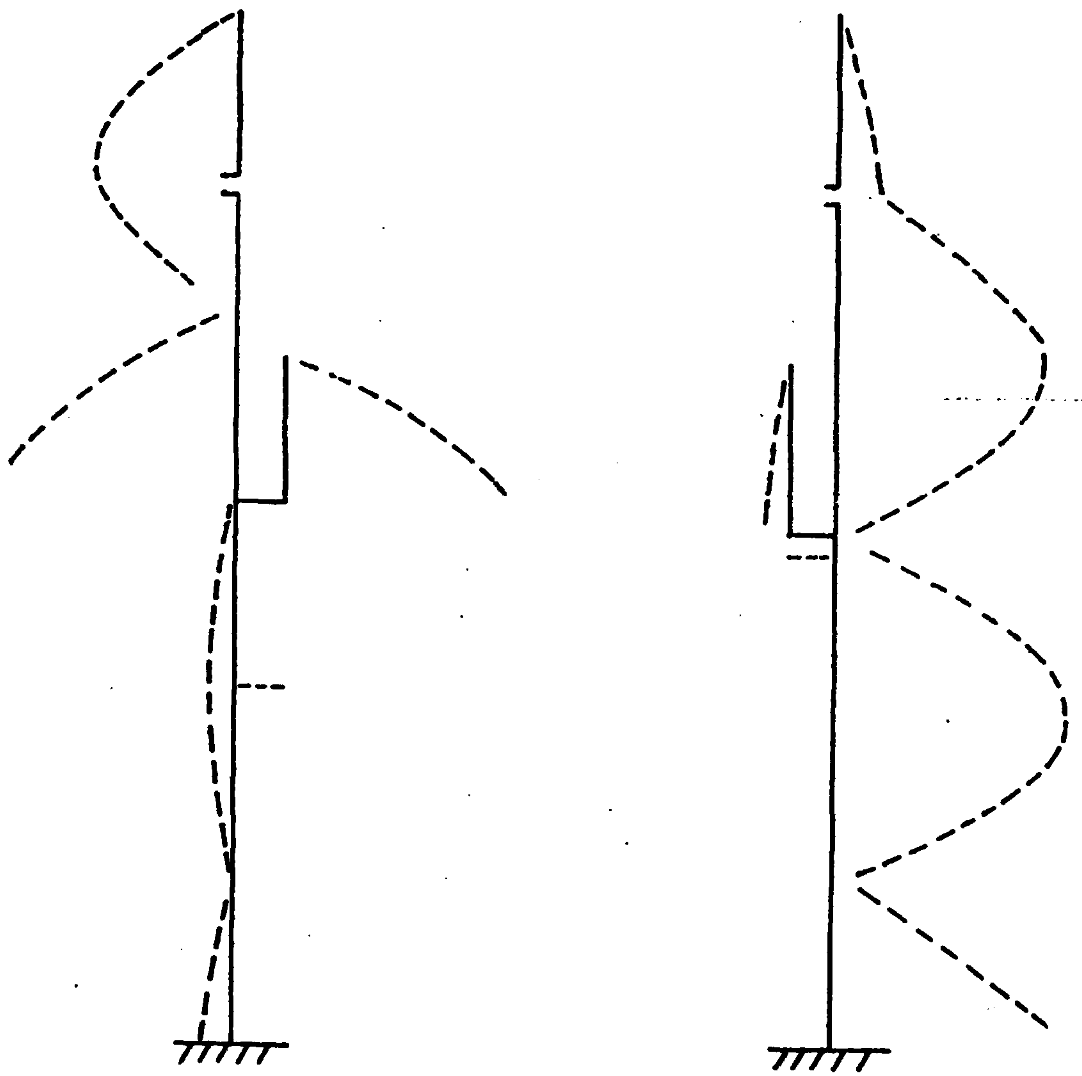

Fig. 5. Currents on Mast-mounted dipole
(a) with resonant stub (b) with non-resonant stub

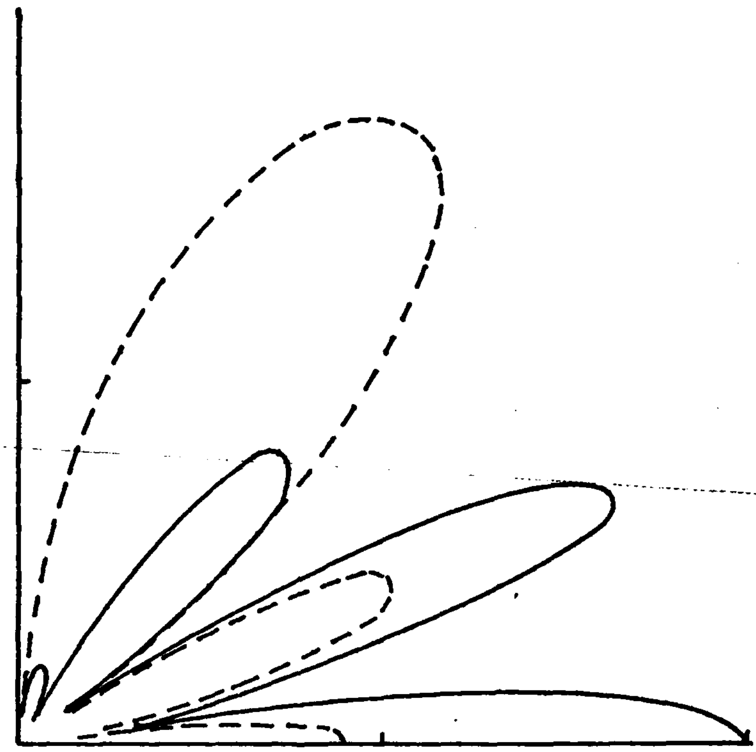

Fig. 6. Vertical radiation patterns of mast-mounted dipoles;
—– non-resonant stub —— resonant stub

lates into greater operating range.

The dipole can also be decoupled from the mast and from the feed line by a cable choke as shown in Fig. 7. To test this hypothesis, a UHF dipole was modeled, using NEC, and the current distribution at 300 MHz determined. The cable choke was assumed to be equivalent to a parallel LC circuit (see Figs. 2(a) and 2(b)) with constants appropriate to UHF. The current is essentially confined to the half wavelength dipole and is relatively weak on the mast or feed line. Even better results could be obtained if the cable choke were resonant at the operating frequency. In this example the LC constants chosen cause the choke to resonate at 258 MHz, which is somewhat lower than the operating frequency. The radiation pattern would be similar to that already shown (Fig. 6) for the antenna with resonant detuning stub.

V. PARASITIC CURRENTS ON A COLINEAR DUAL ANTENNA SYSTEM

In duplex communication systems, the mutual coupling of the collocated transmitting and receiving antennas can result in crosstalk interference. It is well known that radiation coupling between two dipole antennas is minimized when they are mounted colinearly, and sufficiently spaced. A second coupling effect, due to parasitic currents induced on the feed line of the upper dipole, is more difficult to control than radiation coupling. With radiation coupling minimized, this second coupling effect predominates.

It has been demonstrated recently that these parasitic currents can be suppressed over an octave frequency range by means of an "isolator section" incorporated in the feed line of the upper antenna (5). The feed line isolator section consists of a sequence of high impedance cable chokes placed in the coaxial line at quarter-wavelength intervals. It behaves electrically as a band elimination filter which reduces the interantenna coupling caused by currents on the transmission line sheath.

The colinear dual antenna is shown in Fig. 8. The isolator section in this antenna has five cable chokes. The antennas are independently fed dipoles. A computer model of this antenna yields the current distribution shown when the upper dipole is excited, and the lower dipole is terminated in 50 ohms. It is seen that current is essentially restricted to the driven dipole, and is very weak along the rest of the antenna system. The isolation between the upper and lower dipole is defined as the fraction of the total power radiated by one dipole which is intercepted by the other dipole. The interdipole isolation of the antenna system (Fig. 8) was found to be at least 35 dB from 200 to 400 MHz, indicating that radiation coupling is the limiting factor for the given antenna spacing.

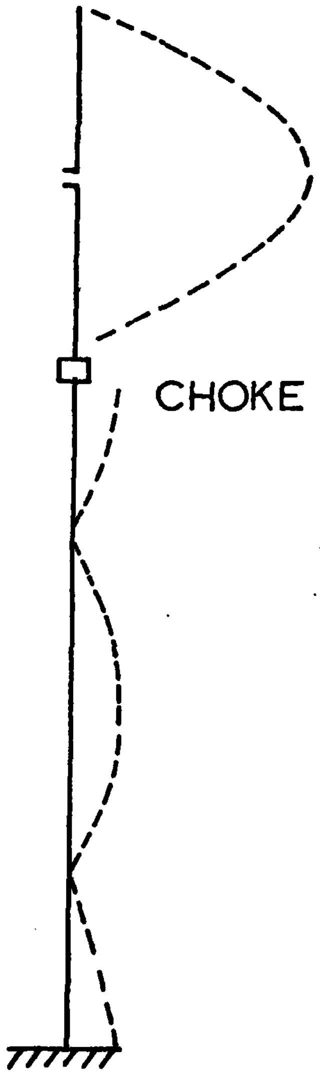

Fig. 7. Mast-mounted dipole with cable choke.

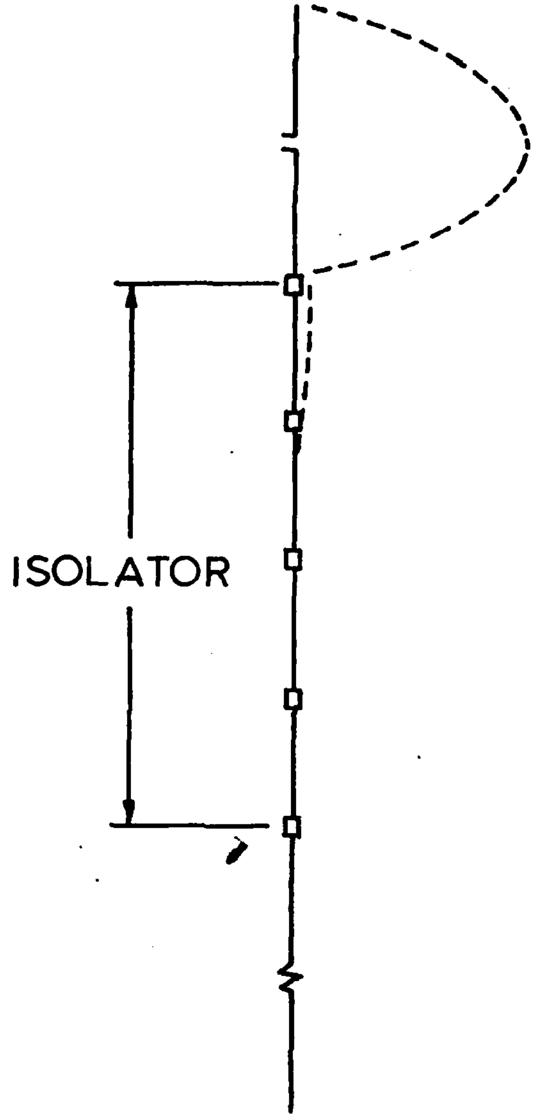

Fig. 8. Colinear dual antenna with isolator section.

VI. CONCLUSIONS

In this paper, it has been clearly shown that induced parasitic rf currents can seriously degrade the performance of a radiating system; yet the significance of these undesired spurious currents has been largely ignored by antenna designers, and field users alike. It has been shown that parasitic currents can be effectively suppressed in both narrowband and wideband antenna systems by means of quarter-wavelength stubs (resonance method) and broadband cable chokes. Although effective current suppression techniques exist, further study is necessary to establish engineering design criteria and to extend state-of-the-art current suppression techniques to multi-octave antenna systems.

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